Birds that will nest in gourds include the following: bluebirds, crested flycatcher, tree swallow (attracted to boxes also, in cranberry bogs, as they relish the cranberry moth), tufted titmouse, wrens (these like gourds the best), downy woodpecker, house sparrow, starling, white-breasted nuthatch, purple martin (the gourds should be placed in direct sunlight, fifteen feet above ground, and far enough apart so they won't knock together).

Winter Storm Shelters

In winter, when temperatures drop, roosting boxes in the garden can serve as warming houses for overwintering species.

Winter Supplementary Food

Severe winter temperatures can be fatal to birds, so it is essential to provide supplementary food for them when the pickings are slim, as a guarantee that they will remain in the vicinity. Placing beef suet, sunflower seeds, millet, and other grains in the orchard will provide birds with the fat and protein that they need.

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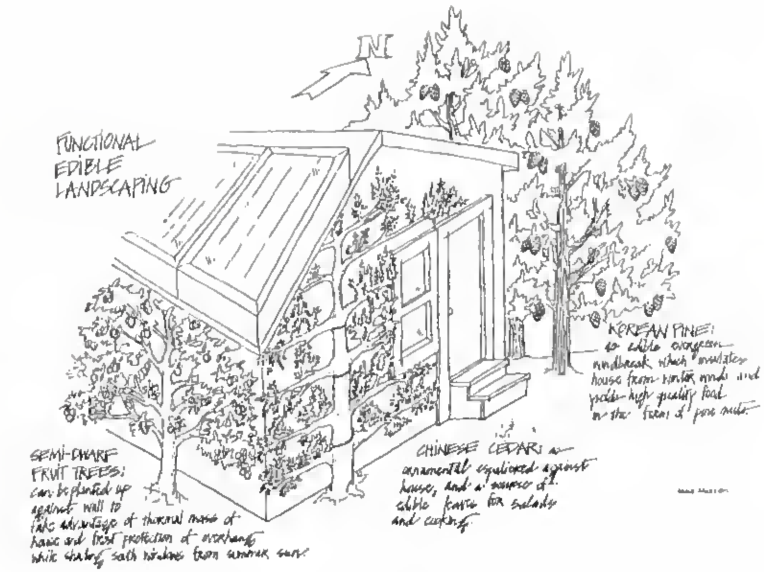
BIRD HOUSES carved out of ornamental gourds



A REPORT from the TREE PEOPLE

Introduction

John Quinney

In recent New Alchemy journals, Earle Barnhart has written on the nature of an ecologically inspired agricultural landscape. His article in the fifth journal begins with a critique of modern agricultural practices and then proceeds to abstract from ecological theory in order to arrive at a description of agriculture modeled on the patterns of native ecosystems. Earle's article in the sixth journal stresses the importance of perennial plants, especially trees, and describes various cultural techniques for propagation, transplanting, and food production in both urban and rural environments. Bill Mollison, a world authority on perennial agriculture working in Australia, has recently described perennial agricultural systems as *permacultures.* In his 1978 book *Permaculture One*[1] he defines the term: "Permaculture is a word we have coined for an integrated, evolving system of perennial or self-perpetuating plant and animal species useful to man [*sic*]. It is, in essence, a complete agricultural ecosystem, modeled on existing but simpler examples."

Taken together, these publications have provided us with the theoretical basis for our agricultural forestry program at New Alchemy. The transition from theory to practice is now gaining expression in sections of the farm; subsequent contributions to this article diagram the process. Much of this work is experimental: we have access to considerations developed by ecologists and foresters, orchardists, and farmers but ultimately our Cape Cod landscape will speak to us more clearly than journals and books.

[1]See reference 3

In addition to the work described herein, we have recently commenced several other projects.

Over the past three years, the number of Chinese weeding geese grazing a grass-alfalfa pasture beneath fruit, nut, and fodder trees has steadily increased. In their own unique and often loveable manner these creatures have impressed us. As biological lawnmowers, fertilizer spreaders, and herbicides they are effective replacements for machinery and fossil fuels. And they taste a lot better than oil!

In this same area a small ecological island has been planted to perennials used by our bees-in-residence. The lee of an evergreen windbreak contains staghorn sumacs (*Rhus typhina*) and a mature pussy willow (*Salix discolor*) interplanted with herbs and flowers.

Near the nurseries we have planted over fifty species of herbs. Over the next few years we will be watching this area closely to determine insect population levels. We will then be able to use particular herbs to provide habitats for specific insects. These predators will assist in establishing biological controls in our gardens and forest.

We continue to collect and propagate potentially valuable trees and shrubs. Among these are Oriental and American persimmons (*Diospyros kaki* and [illegible] ginkgo, [illegible], jujube (*Zizyphus jujuba*), blueberries (*Vaccinium* sp.), elderberries (*Sambucus* sp.), catalpa (*Catalpa* sp.), Buckeyes (*Aesculus* sp.), the Korean nut pine (*Pinus koraiensis*), and shagbark hickory (*Carya ovata*).

Future developments within the agricultural forestry program may include establishing fast-growing hardwoods for firewood, placing nutrient-retrieving plants near trees, working with mycorrhizal fungi, innoculating soils with active earthworm species, evaluating seaweed products for disease control in fruit trees, and establishing living mulches around fruit and nut trees.

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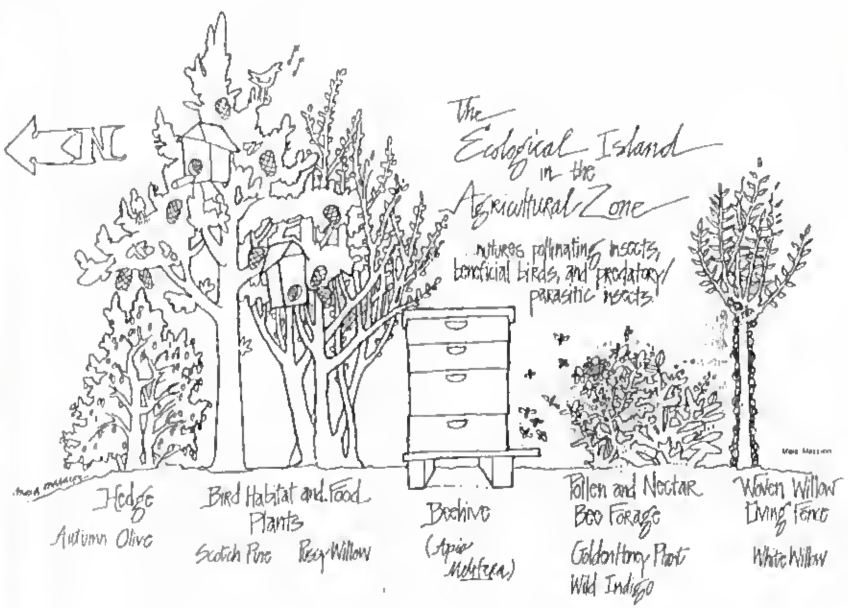


Table I BIRDHOUSE SPECIFICATIONS FOR SELECTED BIRDS

Species	Entrance Diameter (In.)	Entrance Above Floor (In.)	Floor Dimensions (In.)	House Depth (In.)	Box Above Ground (Ft.)	Comments
Bluebird	1½	6–7	5 × 5	8–9	5–10	Prefers on top of fence post
Chickadee	1⅛	6–8	4 × 4	8–10	5–15	2–3 in. wood shavings on floor. Prefers hollow log homes
Red-breasted nuthatch	1	6–8	4 × 4	8–10	5–20	Prefers hollow log-type home
Robin & phoebe	Open front and sides		7 × 7	8	8–12	
Barn owl	6	4	10 × 18	15–18	12–18	
Tufted titmouse	1¼	6–8	4 × 4	8–10	4–5	
Downy woodpecker	1¼	6–8	4 × 4	8–10	6–20	Prefers hollow log. Wood shavings 2–3 in. deep
Hairy woodpecker	1½	9–12	6 × 6	12–16	12–20	Prefers hollow log. Wood shavings 2–3 in. deep
House & winter wren	1 × 2½	4–6	4 × 4	6–8	5–10	Especially likes gourds
Yellow flicker	3	14–16	7 × 7	16–24	6–20	Prefers hollow log homes. Sawdust 2–3 in. deep
Flycatcher (crested)	2	6–8	6 × 6	8–10	8–20	2–3 in. wood shavings

Wood used best at ¾ in. thickness
Martins only ½ in.

are having trouble with the cranberry moth, a box suited to the tree swallow is wise as the tree swallow relishes the taste of the cranberry moth. Birdhouses can be made from hollowed-out gourds, logs, old bark nailed into the trunk of a tree, or three-quarter-inch pine boards (see Table I). Houses should have drainage and ventilation holes and entrance holes. Size and other particulars for each bird have been outlined by the Audubon Society.

Natural Habitat

By providing an environment in which birds can thrive, injurious insects and rodents can be kept to a minimum. Because birds need food, shelter, and water it is important, when purposely attracting birds to an orchard or garden area, to provide enough food for them as an alternative to cultivated fruits and grains. They prefer the taste of wild fruits to cultivated ones. The more diverse the plantings, the better. The following are some suggested plantings:

Shelterbelt plantings:	Russian olive (*Elaeagnus angustifolia*), eastern red cedar (*Juniperus virginiana*), European beech (*Sylvatica fagus*)
Hedgerows:	autumn olive (*Elaeagnus umbellata*), white mulberry (*Morus alba*), Siberian pea shrub (*Caragana aboresecens*).
Fruit-bearing trees:	mountain ash (*Pyrus aucuparia*), honey locust (*Gleditsia triacanthos*), staghorn sumac (*Rhus typhina*).

Many varieties of flowers with their bright colors, fragrant smells, and nectar attract birds. An area left wild as an ecological island in a garden area can provide shelter, food, and beauty for birds and some beneficial insects. Brushpiles provide cover and nesting sites, and can be used as a support for plantings of wild grape or Virginia creeper.

Birdhouses

Forty-nine species of birds have been recorded to have nested in boxes:

Mountain bluebird
Western bluebird
Eastern bluebird
Robin
Chestnut-backed chickadee
Mountain chickadee
Carolina chickadee
Black capped chickadee
Plain titmouse
Tufted titmouse
Red-breasted nuthatch
White-breasted nuthatch
Brown creeper
House wren
Winter wren
Bewick's wren
Carolina wren
Mockingbird
Brown thrasher
Violet-green swallow
Tree swallow
Barn swallow
Cliff swallow
Purple martin
Song sparrow
English sparrow
House finch
Purple grackle
Bullock's oriole
Orchard oriole
Starling
Eastern phoebe
Ash-throated flycatcher
Crested flycatcher
Arkansas kingbird
Red-shafted flicker
Yellow-shafted flicker
Golden-fronted woodpecker
Red-headed woodpecker
Downy woodpecker
Hairy woodpecker
Screech owl
Saw-whet owl
Barn owl
Sparrow hawk
Mourning dove
Wood duck
American goldeneye
Hooded merganser

They Eat
Striped cucumber beetles
Asparagus beetles
Corn root worms
Rose beetle (larvae feed on roots)
Snout beetles—plum and apple curculios
Bean and pea weevils
Grain weevils
White pine borers
Spruce budworms

Bark Gleaners

Many birds dig under the bark of trees for boring and hibernating insects, as well as devouring those on the bark itself.

They Are	They Eat
Woodpeckers	Bark borers
Nuthatches	Hibernating insects (e.g., codling moths)
Creepers	Trunk borers
Chickadees	Timber ants
Warblers	Plant lice
Kinglets	Bark lice
Wrens	

Scraping the old, rough bark from the trunk and branches of orchard trees and covering the bare spots with an adhesive organic mixture [illegible] these insects from nesting. Ringing tree trunks with a metal piece or sticky substance deters some insects from climbing into the tree.

Ground Eaters

A number of birds work on the ground.

They Are	They Eat
Robins	May beetles or June bugs
Bluebirds	Tiger beetles
Blackbirds	Rose beetles
Chipping sparrows	Strawberry slugs
Song sparrows	Root worms
Wrens	Leafhoppers
Warblers	Aphids
Vireos	Crane-fly maggots
Phoebes	Cutworms
Meadowlarks	Cabbage worms
Crows	Root maggots
Bobolinks	Grasshoppers
Flickers	Chinch bugs
Quails	Army worms
Woodpeckers	Craneflies
Catbirds	White grubs
Thrushes	Root borers
Owls	Wireworms
	Bollworms

They Are	They Eat
Hawks	Ants
	Root lice
	Larvae of plum and apple curculios
	Bean and pea weevils
	Grain weevils
	White pine borers
	Ants (Formicidae)
	Thousand-legged worms (subclass Myriapoda; destructive to strawberries, but some predaceous.)
	Frogs
	Lizards
	Snakes
	Mice
	Moles
	Shrews
	Groundhogs
	Squirrels
	Gophers

Predatory Birds

In winter, mice, moles, groundhogs, rabbits, and other mammals can cause considerable damage to the roots and trunks of orchard trees. Such rodents normally can be discouraged from chewing the bark of trees by wrapping burlap and/or wire mesh around the trunks of trees. Not all damage is inflicted at this level, however. The pine mouse burrows underground to chew the trunk and roots below ground level. Groundhogs will tunnel throughout the root systems of orchard trees and expose the roots to oxygen in the atmosphere, this can dehydrate them and eventually kill the tree.

Owls and hawks frequent areas where small mammals are plentiful and help to keep their numbers down. Owls can be attracted to houses of an appropriate size and can act as live-in rodent controls.

Bird Habitat

There are birds who can be persuaded to forsake their natural habitats and live in artificial structures. The destruction of forests and the thinning out of dead trees in orchards and woodlands has reduced the number of available nesting sites for many birds. If birdhouses are erected in late winter, before the birds are scouting for nesting locations, many birds will take up residence in them, some returning year after year. If a specific bird is required, it is best to put up a birdhouse specifically designed for that bird. For example, if you

Surveying and Grafting Local and Antique Fruit Trees

Mavis Clark

We have undertaken the task of surveying the growth of fruit trees in the Upper Cape area in an effort to find varieties that are adapted to grow well under our local climatic conditions and to show resistance to diseases prevailing in the area. We aim to propagate such trees for further planting throughout the town of Falmouth.

Cape Cod has the reputation of being a very poor area for growing fruit, because its moist, foggy weather favors the rapid spread of fungal diseases, blights, and scabs. Commercial orchardists, now very few in number, spray their trees once every week during the growing season to combat these diseases and aphids, scale insects, borers, and caterpillars as well.

In 1977 and 1978, Earle Barnhart began the search for trees that seem well adapted to the Cape and are known for bearing consistently good crops. He enlisted the reliable food-foraging instincts of adolescents by asking Falmouth High School students to pinpoint such trees. This source of local lore produced a list of apple, pear, and peach trees that we started to check out in more detail. The 1977 research, which also included a survey of all the local history books in the Falmouth Public Library, revealed that the earliest settlers brought stock and seeds of fruit trees with them and established orchards that supplied them with plentiful fruit.

Once Earle had tracked down high-bearing trees, he encountered owners that were usually apologetic that their trees had been neglected. Everyone was very generous in allowing us to cut off young branches for scions in February 1978. After cold storage, these either were used for whip or wedge grafts in April, or budded in June. In 1977 Earle had planted the rootstock apple trees onto which these grafts were later made, using seeds from a commercial nursery. The seeds originated from wild trees in upstate New York. We have kept growth records of the rootstock trees, photographed them each year. They now stand about three feet tall. During the summer of 1979 we successfully grafted scions from several dozen grafts of local trees unto the rootstock. At that time we planted four antique trees and they were ready to have scions taken from them by the following spring. We shall check the local trees at harvest to try to identify varieties or at least to suggest possible parentage for them. As peach trees are better propagated by late spring budding, we shall graft local tree buds onto New Alchemy trees and onto some planted in a neighboring yard as well.

We were given much help and information by Howard Crowell, of Crow Farm, Sandwich, Massachusetts, who runs a fine commercial orchard. He retains some antique apple varieties along with many newer ones, numbering nineteen in all. He finds that although the russet apple does not bear as heavily as newer varieties, devotees of this fruit will come to buy russets and usually go off with other fruits and vegetables too. This old variety also shows a high natural resistance to diseases. We returned from Crow Farm with many scions, chiefly the antique and more naturally resistant varieties.

We are seeking out other resource people on the Cape knowledgeable of fruit orchards. Their hard-earned experience could help point up to us early mistakes and lead us in turn to new investigations.

Recycling Leaf Nutrients

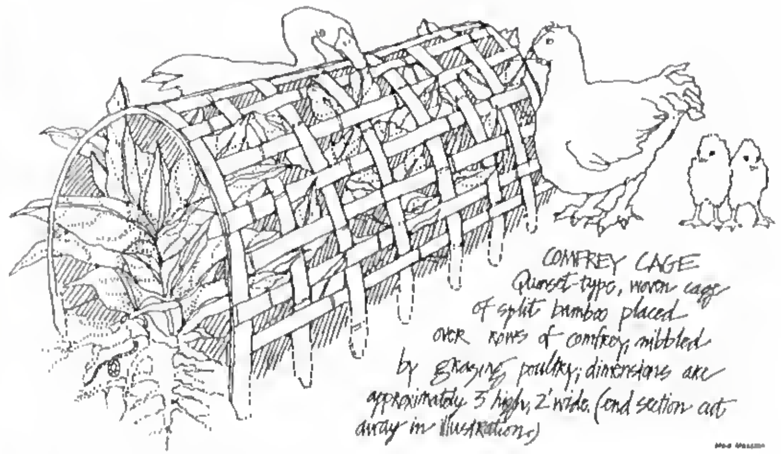
Ed Goodell

For a good many years now we have been asking area residents to bring us their leaves in the fall. People seem to like to do this, and our soil thereby receives a sizeable amount of nutrients.

The soil-conditioning properties of leaves are especially appreciated on our poor, sandy soils. Because of its capacity to absorb water and exchange nutrients, adequate humus is essential for a healthy soil. The humus formed from leaf decay has a long life because leaves contain relatively high proportions of lignin and hemicellulose, the most lasting constituents of humus.

At New Alchemy we have realized the value of leaves for quite a while. An early demonstration of the benefits they confer was provided when a young Chinese chestnut tree was planted on the site where a leaf pile had been the preceding year. Of 20 Chinese chestnuts planted at the same time, it rapidly outgrew the others.

We have used leaves regularly in moderate amounts for winter mulches, for trench composting between intensive garden beds, and for mulching trees. The leaf mold—the dark, crumbly humus formed by gradual fungal decay and weathering—from underneath the piles is in high



demand for potting soil. We have turned leaves under the soil in the fall to decompose over the winter. We have also tried transforming sod into a growing medium by mulching it thickly. This was useful for growing potatoes and winter squashes. We are planning to use a large bin of leaves in the first stage of graywater treatment. Bags of leaves can be convenient and effective insulators around foundations, beehives, and tender young plants.

The amount of leaves at our disposal has increased dramatically since the fall of 1978, when we put up a sign at the Falmouth dump directing potential leaf donors to the farm. The leaf pile has advanced ... yards from the original storage area. We remove leaves from the end opposite that to which they are added. As a result, the pile creeps slowly across the landscape, leaving a swath of nicely mulched, worm-worked soil. You may have heard of chicken tractors.[1] Apparently we have created a leaf tractor. Steering is easily accomplished with movable signs that indicate where the leaves should be deposited.

During the winter of 1979–1980 we estimate that we were given 750 cubic yards (575 cubic meters) of leaves weighing over 15 tons (13.6 metric tons). This amount of mixed leaves contains 230 lb, or 105 kilograms (kg), of nitrogen, 80 lb (36 kg) of phosphorus, and 130 lb (59 kg) of potash.[2] In terms of N-P-K (nitrogen-phosphorus-potassium), this is roughly equivalent to 1,000 lb (455 kg) of 20-10-10 fertilizer, or enough to apply more than 100 lb/acre (112 kg/hectare) annually to the entire farm. In addition to the other nutrients the leaves contain significant amounts of calcium, magnesium, and trace minerals.

Unlike the soluble nutrients in chemical fertilizers, those contained in leaves are released gradually as the leaves decay. Leaf decay can be thought of in terms of the half life of the leaves—the time it takes half of the material to decay. The half life of a leaf on the forest floor is 12–18 months. The decay process can be hastened by turning the leaves into the soil, shredding them, or piling them together.

Our current contributions of leaves far exceeds New Alchemy's capacity to use them. This enables us to accumulate large amounts of leaves for the two or three years required for them to decompose fully into leaf mold. A delight for worms and gardeners alike, leaf mold holds three to five times its weight in water, has no weed seeds, has a pH of 5.5–5.0, and is very enduring in the soil. We use it for potting soil, to top-dress individual plants, and, when available, for broad-scale mulching. Since New Alchemy has prospects of a generous supply of leaf mold, it will probably become our all-purpose soil amendment.

Ultimately, we would prefer that the leaves return to the soil from which they grew, to enrich that soil directly. We would like to see our leaf donors use their own leaves, and some of our educational efforts concern ways to encourage this. In the meantime, the productive capacity of our soil will continue to grow as we enrich it with a fertile mantle of leaf mold.

[1] Richard Merrill, ed. *Radical Agriculture*. N.Y.: Harper & Row.
[2] Bulletin No. 92, Clemson Agricultural College, Clemson University, South Carolina.

Birds and Biological Pest Control

Loie Urquhart

In observing the natural world, it is quite evident that birds help to regulate the numbers of insects and rodents. But since the advent of pesticides, comparatively little attention has been paid to encouraging birds as predators in the forest, orchard, field, and garden.

Birds can eat thousands of insects in a single day, especially in the spring, the season of highest consumption, when the birds are feeding their young. Owls and hawks prey upon mice, rabbits, and other small mammals that can damage fruit trees. In the winter, nonmigratory insect eaters such as woodpeckers, chickadees, and nuthatches search the bark of trees for hibernating insects.

By providing nesting sites, water, and winter shelter, we could encourage and foster populations of beneficial birds that would regulate insect and mammal pests.

Feeding Habits of Birds

Surveys of the feeding habits of birds conclude that the terms insectivorous and vegetivorous indicate predominance in a given diet, rather than restriction to one type of food. For instance, the most exclusive vegetarians—the finches, grouses, and pigeons—sometimes eat insects, while the most avid insect eaters—the swallows and flycatchers, will eat berries.

From the viewpoint of the farmer or orchard grower, insects can be classed as beneficial (which includes parasitic and predaceous varieties) injurious, and neutral. Birds do eat beneficial insects, but only, it seems, to the extent that keeps their numbers in proportion and maintains an equilibrium in the natural continuing flux.

Injurious insects are found in the air, on and within leaves, on and under the bark of trees (boring or hibernating insects), and on the ground. There are insects, such as the Mexican bean beetle, the monarch butterfly, and some insects of the suborder Heteroptera, that are protected from being eaten by birds by either a hard casing, a disagreeable odor and taste, or a camouflaging ability to meld into their surroundings. Birds that prey on insects can be grouped loosely, as the flying insect patrol, the foliage cleaners, the bark gleaners, and the ground eaters.

The Flying Insect Patrol

There are a number of birds who feed while in flight.

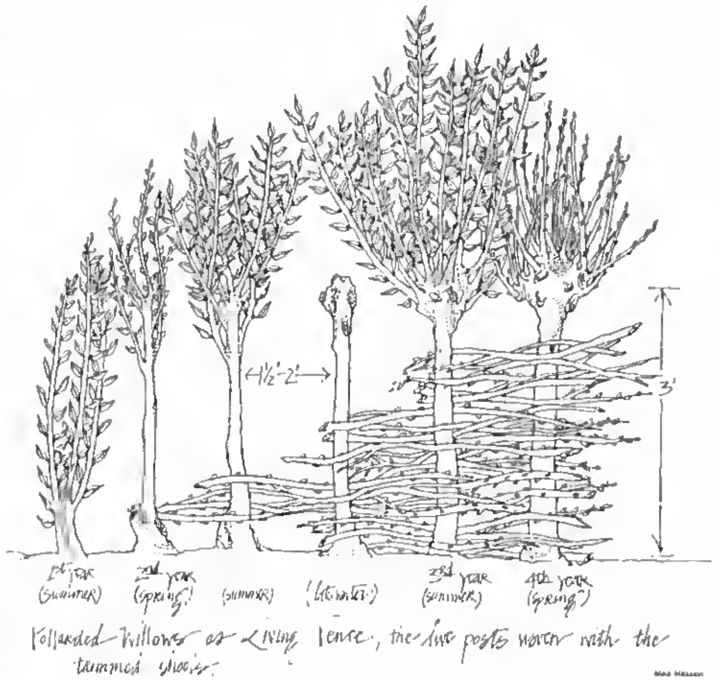
Daytime Patrol	*They Eat*
Swifts	Moths—gypsy moths
Swallows	Cabbage worm moths
Martins	Codling moths
Kingbirds	Cankerworm moths
Phoebes	Leaf-roller moths
Flycatchers	Locusts (short-horned grasshoppers)
Vireos	Long-legged crane flies
Redstarts	Leafhoppers
Peewees	Aphids
Mockingbirds	Long-horned grasshoppers
Catbirds	Hessian flies (wheat enemy)
Hawks	Horseflies
	Rose chafers
	Winged ants
	Butterflies
	Beetles

Nighttime Patrol	*They Eat*
Nighthawks	Night-flying or owlet moths (*Noctuidae*)
Whippoorwills	Moths—cotton boll worms
	Army worms
	Cutworms
	Mosquitoes
	Leafhoppers

Foliage Cleaners

Foliage cleaners concentrate on picking destructive insects off the leaves and branches of plants.

They Are	*They Eat*
Warblers	Leafhoppers (*Jassidae*)
Nuthatches	Plant lice or aphids (*Aphidae*), including common "green fly"
Chickadees	Leaf-rollers (e.g., codling moths)
Kinglets	Leaf-miners (e.g., apple leaf miners)
Robins	Cankerworms
Catbirds	Cutworms
Thrushes	Cotton boll worms
Ruffed grouse	Army worms
Baltimore orioles	Hairy caterpillars
Blackbirds	Tent caterpillars of apple and wild cherry trees
Crows	Fall webworms
(many others)	Tussock caterpillars
	Gypsy moth larvae
	Leaf beetles—Colorado potato beetles
	Flea beetles



ducks, and turkeys. Hedgerows planted in an east-west orientation can create local microenvironments with raised temperatures on the southern exposure. Such microenvironments allow the survival of plants and animals that might otherwise be absent from the landscape. Prunings from nitrogen-fixing hedgerows can be used as mulches around fruit and nut trees in order to supply some of their nutrient needs.

Although our work at New Alchemy is mainly with hedgerows, another kind of boundary is traditional here. In the years when our part of Cape Cod was extensively farmed, local stone was used for the construction of dry stone walls. Many of these walls still remain in areas of the Cape that have become forested. Their construction is admittedly labor intensive, but they have the advantages of being relatively permanent, made from a local resource, and largely maintenance free. Although these walls are obviously limited in their ecological functions, they offer a viable alternative to hedgerows and introduce a pleasant diversity to the landscape.

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Nitrogen-Fixing Trees and Shrubs

John Quinney

Nitrogen is the most abundant element in the earth's atmosphere and is essential for plant growth and reproduction. However, atmospheric nitrogen can be utilized directly by plants only after it has been converted to either its nitrate or its ammonium forms. This process is known as fixation and can be achieved either chemically or biologically.

Chemical fixation involves the reaction of atmospheric nitrogen with hydrogen from natural gas at elevated temperatures and pressures in the presence of a catalyst—the Haber process. The ammonia thus produced can be applied directly to farmland or converted chemically to other nitrogenous fertilizers.

Biological fixation of nitrogen is carried out by a number of free-living organisms and also, most importantly, by virtue of two symbiotic associations between plants and bacteria—the rhizobium-legume association and the actinomycete–nonleguminous-angiosperm association (Table 1).

Chemical fixation is an energy-intensive process; it depends on diminishing supplies of fossil fuels. The chemical production of 150 kilograms (kg) of nitrogenous fertilizer (a typical per hectare application) requires 1.53 million kilocalories (kcal). For comparison, biological fixation of the same amount of nitrogen by the legume winter vetch (*Vicia villosa*) involves a seeding cost of only 90,000 kcal.[1]

Many farmers meet the nitrogen requirements of their land by planting legumes as green manure crops or as a part of crop rotations. Used in these

[1]Pimentel et al., 1975. Reference 7

Table 1 MAJOR PRESENT-DAY NITROGEN FIXING PLANTS[1]

1. *Free-Living Organisms*
   a) Heterotrophic bacteria, e.g., *Azobacter, Clostridium, Spirillum, Beijerinckia, Klebsiella*
   b) Autotrophic bacteria, e.g., *Rhodopseudomonas, Rhodospirillum, Thiobacillus*
   c) Blue green algae, e.g., *Anabaena, Calothrix, Nostoc, Plectonema*, etc.
2. *Root Nodule Forming Symbioses*
   a) Rhizobium-legume associations, e.g., *Glycine max* (soybean), *Phaseolus vulgaris, Vicia faba* (vetch), *Trifolium repens* (clover), etc.
   b) Actinomycete–nonleguminous angiosperm associations, e.g., *Alnus glutinosa* (alder), *Robinia pseudoacacia* (black locust), *Hippophae rhamnoides* (sea buckthorn), etc.
   c) Cycad–blue green-algae associations, e.g., *Bowenia, Cycas, Encephalartos*, etc.

[1]Source: W. P. D. Steward, 1977. *Ambio* 6:166.

ways alfalfa (*Medicago sativa*) and soybeans (*Glycine max*) can supply up to 450 and 100 kg nitrogen per hectare per year (N/ha/yr) respectively. However, not all legumes are capable of fixing nitrogen; for example, the legume Eastern redbud (*Cercis canadensis*) does not form root nodules and thus does not fix nitrogen.

The nonleguminous nitrogen-fixing plants, which are all trees and woody shrubs, have recently been recognized as an important source of fixed nitrogen. For example, alders (*Alnus* sp.) can fix up to 300 kg N/ha/yr and the sea buckthorn (*Hippophae rhamnoides*) up to 180 kg N/ha/yr. In temperate-region forested biomes the nitrogen-fixing trees and shrubs are usually [illegible] species modifying the soil environment and establishing favorable conditions for succeeding trees. For example, in the Pacific Northwest the red alder (*Alnus rubra*) is succeeded by Douglas fir (*Pseudotsuga menziesii*); on Cape Cod, bayberry (*Myrica pensylvanica*), sweet fern (*Comptonia peregrina*), and black locust (*Robinia pseudoacacia*) are followed by pitch pine (*Pinus rigida*), and various oaks (*Quercus* sp.).

The nitrogen-fixing trees and shrubs make nitrate available to other species mainly through leaf fall; the nitrate enters the soil when the leaves are decomposed by soil microorganisms. Only when the bacterial root nodules are sloughed off or the host plant dies can nitrogen be made available more directly. As a forest matures and the nutrient cycles tighten because the forest has become increasingly efficient at processing organic matter, nitrogen usage is increasingly conservative, and the need for nitrogen fixation is correspondingly reduced. In these ecosystems the small nitrogen requirements needed for plant structural tissue and to replace losses by leaching are met mainly through fixation by various free-living organisms (see Table 1).

In the agricultural forestry work at New Alchemy, nitrogen-fixing trees and shrubs are important components of the overall ecology.

At New Alchemy the following nitrogen-fixing trees and shrubs are being studied:

Legumes:	black locust, Scotch broom (*Cytisus scoparius*), Siberian pea shrub (*Caragana arborescens*), *Albizzia julibrissin*, and honey locust (*Gleditsia triacanthos*) (nitrogen-fixing ability not firmly established).
Nonlegumes:	bayberry, sweet fern, autumn olive (*Elaeagnus umbellata*), Russian olive (*Elaeagnus angustifolia*), *Ceanothus* sp., alders (*Alnus rugosa, A. glutinosa*), and sea buckthorn.

A collection has been established that now consists of plantings of honey locust, *Albizzia*, black locust, Scotch broom, autumn olive, and bayberry. Additional species will be added over the years. This area will be used for education as well as for testing the growth of these trees and shrubs in the Cape Cod environment and providing propagation materials.

The honey locust and the alders are useful fodder trees. In New Zealand, cattle have been fed on honey locust pods; they fall from the trees over the three to four months of winter when other fodder is in short supply. Foliage from alders has been processed into silage and used to feed cattle, and at Hampshire College in western Massachusetts *A. rugosa* is being evaluated as a sheep feed. In due course these species will be tested at New Alchemy as livestock feeds, especially for geese and poultry.

We have begun various interplanting experiments in the polycultural forest area south of the Ark. Literature reports have documented the beneficial effects of black locust, alders, and autumn olive on the growth of interplanted timber trees, apples, and black walnuts respectively. A stand of young black locust trees occurs naturally in a section of this area, and we shall manage these trees with some attendant controls on their propagation through vegetative spreading.

We have established experimental hedges of autumn olive and are propagating the tree by root and stem cuttings. The roots of these plants are well nodulated. We are planning hedgerow plantings of Siberian pea shrub, Russian olive, and *A. glutinosa*.

There is a named variety of the black locust (var. "*rectissima*") that produces straight, durable lumber. Root cuttings of this variety, which is also known as the "ship-mast locust," are being sought. We hope to acquire and test additional species of nitrogen-fixing shrubs such as *Ceanothus* sp. and sea buckthorn.

We expect that careful integration of a variety of nitrogen-fixing species in our agricultural forests will make a substantial contribution to the productivity of the forests in a way that is both energetically conservative and environmentally gentle.

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Hedgerows and Living Fences

John Quinney

In any agricultural landscape the most obvious function of fences and hedgerows is to control the movement of animals—domestic and wild—so they will be excluded from food crops or selectively rotated through pastures. The advantage of hedgerows over fences is that they are multifunctional components of the landscape and as such can be integrated with the overall design strategy.

Perhaps one of the best-known examples occurs in the traditional English landscape. The English hawthorn (*Crataegus* sp.) was often originally planted to replace wooden post-and-rail fences, which are subject to inevitable decay. As well as providing an impenetrable barrier to the movement of sheep and cattle, such hedges have other important ecological functions. They provide a habitat for a wide variety of beneficial insects and birds. They facilitate the establishment of numerous volunteer herbs and "weeds." Cattle, sheep, and horses grazing on pastures thus enclosed have often been observed browsing these plants as well, presumably supplementing their diet with nutrients not available in the relatively simple pasture ecosystem. In windy areas of the country, especially East Anglia, the hedgerows reduced soil erosion, a function that has only become apparent since their removal for the sake of "efficient" large-scale agriculture.

At The New Alchemy Institute an experimental hedge of autumn olive (*Elaeagnus umbellata*) has been established and pruned to encourage dense bottom growth. An immediate goal of these plantings is to control the movement of domestic geese, restricting their access to the gardens and tree nursery.

We have also planted living fence posts of willows (*Salix* sp.). Eventually, prunings from the top of each fence post will be woven between them, providing an effective barrier. Ultimately, annual pruning will yield firewood.

These and other successive hedge plantings will be designed in order to create ecological landscape elements with diverse functions. They will be, in effect, ecological islands in which a variety of plants and animals may grow undisturbed by cultivation. They will be windbreaks and a source of food for a variety of birds and animals. For example, the Russian olive (*Elaeagnus angustifolia*), an important Midwest hedgerow species, is known to be used for food by at least forty birds, including chickens.